Jet Propulsion Laboratory,
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# 2018 Europa Lander Architecture Update
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### Context

Jupiter's icy moon Europa is a prime target in our exploration of potentially habitable worlds beyond Earth. The combination of a subsurface liquid water layer in contact with a rocky seafloor may yield an ocean rich in the elements and energy needed for the emergence of life, and for potentially sustaining life through time. Europa may hold the clues to one of NASA's long-standing quests – to determine whether or not we are alone in the universe. The *Europa Lander Study 2016 Report* described recommendations for the science requirements and model payload consistent with the goal of searching for signs of life on Europa's surface. Based on the Model Payload and direction from HQ, the Europa Lander Pre-Project prepared and presented a technically viable concept at the Mission Concept Review (MCR) in June of 2017 as shown in Fig. 1. However, the cost estimate of that concept was higher than thought supportable by the SMD budget on the schedule proposed. The review board asserted in their report that the Europa Lander Pre-Project "would clearly benefit from an appropriate cost constraint that would result in a focused, yet rich, mission consistent with those in NASA's planetary science portfolio."

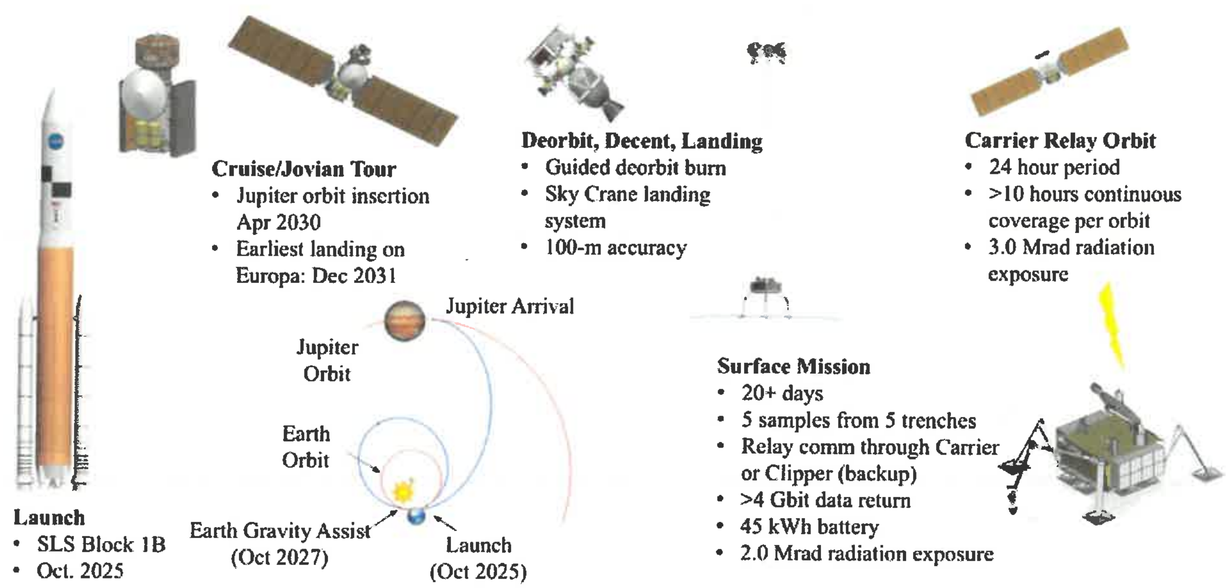


**Figure 1. Overview of Europa Lander Relay Architecture at the Mission Concept Review**

Based on the recommendations of the MCR board and input from the Pre-Project, Dr. Thomas Zurbuchen, Associate Administrator of the NASA Science Mission Directorate (SMD), directed JPL to "convene a team to explore multiple design options for a future Lander, consisting of selected Lander MCR Board Members, selected mission design experts from JPL and/or APL, scientists, and HQ/customer representation." The team was directed to explore architectural options for a potential Europa Lander. The charter was to "design-to-cost," with "science vs. cost trades expected." The SDT report represents the most capable science mission under consideration, but "reduced science objectives may be proposed to achieve lower cost and lower capability mission designs." Multiple variations were considered from the MCR baseline. The science re-scope and a Direct to Earth (DTE, i.e., eliminating the communications relay) architecture were found to reduce cost and cost risk while still providing a compelling science mission. In December of 2017, Dr. Zurbuchen directed the Pre-Project to adopt the DTE Solar Power architecture variant and move forward with the baseline concept necessary to support payload planning and development. A description of and rationale for the changes to the science and mission architecture, as previously captured in the *Europa Lander Study 2016 Report,* are described below. This summary is intended to provide additional context for the draft Europa Lander Proposal Information Package (PIP) provided with the Instrument Concepts for Europa Exploration 2 (ICEE-2) ROSES amendment.

**Science Update**

In response to feedback from the post-MCR reformulation panel, Goal 1 was rescoped to focus on a search for biosignatures, as opposed to requiring the ability to definitively detect life, were it to be present in Europa's ice. Though subtle, this is an important change that enables several reductions in the complexity of the overall mission architecture as described below. This change also addresses two points that were emphasized throughout this review process: 1) the operational scenario for potential life detection is challenging, and 2) the mission should ensure that investigations not related to life detection are retained.

The *Europa Lander Study 2016 Report* defines a biosignature as 'a feature or measurement interpreted as evidence of life.' As detailed in Chapter 5 of that report, life detection would necessitate multiple lines of complementary and redundant evidence, each of which is a biosignature. Furthermore, repeat analysis of the sampled material would be required to corroborate the validity of each line of evidence. Operationally, the science team would require a high cadence of ground-in-the-loop (GITL) opportunities to make decisions about sampling, and the value of a given sample for life detection. This framework for life detection is robust, but introduces many operational complexities that can be alleviated by reducing the scope to searching for biosignatures, as opposed to life detection. Focusing on a search for biosignatures enables several significant operational changes, such as a reduction in the number of GITL opportunities, the number of samples and trenches, and a reduction in the science data volume.

Searching for biosignatures has the benefit of maintaining the capability for life detection by retaining Goal 1, its Objectives, Investigations, and associated model payload, while removing much of the operational burden. This re-scope also served to preserve Goal 2 (Habitability) and Goal 3 (Context) Objectives and Investigations.

**Architecture Update**

An overview of the DTE mission architecture is shown in Fig. 2 with changes in key features identified in bold. Key parameters for the two mission concept architectures are summarized in

Table 1. Throughout the formulation activity, the mass and volume allocations for the identified model payload elements were protected and are unchanged from *Europa Lander Study 2016 Report.*

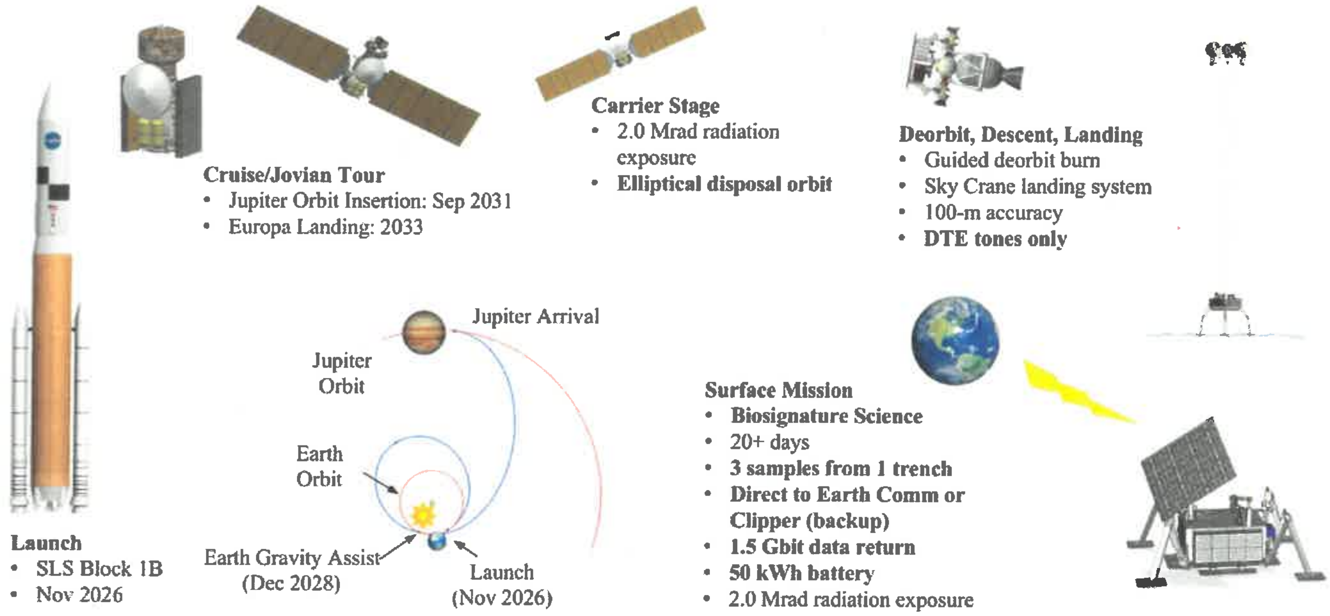


**Figure 2. Overview of Europa Lander Direct-to-Earth Architecture Concept**

A relay architecture was initially chosen because the ~3-meter class antenna (similar to Clipper's high gain antenna (HGA)) would add significant mass, volume, and cost to the Lander's design when compared to the baseline 0.3-meter antenna used to communicate with a relay asset. During the reformulation activity, the Pre-Project team worked with telecom engineers to survey the latest technology developments and identified a high efficiency, flat panel antenna technology derived from the Juno microwave radiometer (MWR) array. The reduction in data volume from >4 Gbit to ~1.5 Gbit flowing from the re-scoped science combined with a higher efficiency HGA array made the DTE architecture a viable candidate. The change from a relay to a DTE architecture has a number of implications.

In the case of the relay architecture, the data rate from the Lander to the Carrier was 1 Mbps, resulting in very small transmit times and minimal energy cost from the Lander, while the data rate from the Carrier to Earth was 80 kbps. The 24 kbps return from the DTE Lander requires a higher power amplifier and longer transmit times, which together result in a significant increase in Lander energy per returned bit. That energy cost is off-set by a reduction in the activities associated with trenching, collection and sample analyses, as well as the science and engineering data associated with those activities. The required pointing accuracy from the surface to Earth is higher than was needed for return to the Carrier and requires the Lander to determine its attitude on the surface.

The removal of the data relay function has the potential to eliminate the requirement for the Carrier stage to operate as a standalone spacecraft with dedicated avionics, GN&C sensors, and telecom subsystems as long as the stage can be dispositioned as required to comply with planetary protection (PP) requirements. In the MCR concept, a number of delivery trajectories and relay orbits were under study, with the Carrier delivering the Deorbit Vehicle (DOV) after a 2 hr coast to an altitude of 6 km at 80 km uptrack of the landing site, where the SRM is ignited for the deorbit burn. In the DTE architecture, the Cruise Vehicle is placed into a stable elliptical orbit around

Europa that meets the PP requirement. The DOV executes a periapsis drop maneuver resulting in additional fuel load on the Descent Stage (DS).

## Surface Operations Update

The surface phase encompasses the Europa Lander science activities, planned for a duration of approximately 20+ (Earth) days, during which time the Lander is expected to complete the required number of sample acquisitions. Key differences between the relay and the DTE architecture are the cadence of communications, the opportunities for GITL decision making and number of command cycles. Several aspects of the surface strategy are common to both architectures. Unchanged is the expectation that due to the limited number of GITL opportunities, a sample cycle is a fully autonomous sequence of events that is performed with no real-time interaction with Earth.

**Table 1. Key Parameters for Relay and Direct-to-Earth Architecture Concepts**

| Parameter | Value for Relay Architecture | Value for DTE Architecture |
|---|---|---|
| Science payload mass (with margin) | 42.5 kg | 42.5 kg |
| Science payload volume | 34.5 L | 34.5 L |
| Number of samples to be collected for in situ analyses | 5 (Baseline scenario) | 3 |
| Baseline number of trenches | 5 | 1 |
| Required sampling depth capability | 10 cm | 10 cm |
| Required minimum sample volume | 7 cubic centimeters per sample | 7 cubic centimeters per sample |
| Limit of detection for organics | 1 picomole in a 1 gram sample | 1 picomole in a 1 gram sample |
| Limit of detection for cells or cell-like structures | 0.2 microns, at a concentration of 100 cells per cubic centimeter of ice | 0.2 microns, at a concentration of 100 cells per cubic centimeter of ice |
| Duration of surface science phase | 20+ days (Baseline scenario) | 20+ days (Baseline scenario) |
| Energy source | 45 kWh from primary batteries | **50 kWh from primary batteries** |
| Radiation shielding | Provided by central vault, with exception of externally-mounted context remote sensing | Provided by central vault, with exception of externally-mounted context remote sensing |
| Data link to Earth | Provided by dedicated Carrier Relay Stage (CRS) | **Provided by Lander HGA Direct-to-Earth** |
| Data volume capability (Total) | > 4 Gbits from Europa via CRS | **1.5+ Gbits from Europa via DTE** |
| Data volume allocation (Science CBE +uncertainty) | > 2 Gbits | **600 Mbits** |
| Contingency communications capability | Compatible with Clipper | Compatible with Clipper |
| Decisional data volume for documenting/analyzing a sample | 50 Mbits per sample | 50 Mbits per sample |
| Time allowed between instrument power-on and ready to receive sample | 60 minutes | 60 minutes |
| Time for analysis instrument suite to generate decisional data | 4 hrs per sample | 4 hrs per sample |
| Time for analysis instrument suite to complete all analyses | 10 hrs per sample | 10 hrs per sample |
| Instrument ground operations (within | NA | 6-8 hours |

| | | |
|---|---|---|
| same Earthrise period) | | |
| Instrument ground operations (between distinct Earthrise periods) | NA | 36-48 hours |
| Total Instrument Energy (CBE+uncertainty | 2500 Whrs | **1600 Whrs** |
| Baseline seismic monitoring | 10 days | **7 days** |
| Baseline completion | 12 days | **7 days** |
| Number of command cycles | 20 | **10+** |
| Launch vehicle | Space Launch System | Space Launch System |
| Earliest launch date | 2024-2025 | **2026-2027** |

## Conclusion

The evolution of the Europa Lander mission concept after the *Europa Lander Study 2016 Report* was released has resulted in a focused, yet rich, baseline mission consistent with those in NASA's planetary science portfolio. The science re-scope to a search for biosignatures relaxed some operational constraints and the reduction in the number of samples and number of trenches yields energy, data volume, and overall mass savings. The science measurements and model payload of the Lander mission presented in the *Europa Lander Study 2016 Report* have been protected through this architecture evolution, with mass, volume and power allocations unchanged. If biosignatures are present in Europa's ice at a level comparable to one of the most extreme and desolate of environments on Earth (Lake Vostok ice), then this mission concept could detect them in Europa's icy surface. However, this mission is also designed to generate an incredibly valuable dataset about the chemistry of Europa's ice shell, its putative ocean, and the geological and chemical context for habitability.

The information presented about the Europa Lander concept is pre-decisional and is provided for planning and discussion purposes only.

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